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Lake Level Drawdown as a Macrophyte Control Technique

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16. ABSTRACT

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Journal Article

LAKE LEVEL DRAWDOWN AS A MACROPHYTE CONTROL TECHNIQUE[1]

G. Dennis Cooke[2]

ABSTRACT: Lake drawdown as a management or restoration technique for controlling macrophytes in eutrophic lakes is reviewed for effectiveness, longevity, and positive and negative impacts. Drawdown can be effective but is species specific, and some nuisance plants are resistant or stimulated. The responses of 63 nuisance plants are reviewed. Advantages of the technique include low cost, absence of toxic chemicals, enhancement of fisheries, and the opportunity to carry out other lake improvements. Drawbacks include nutrient release, algal blooms, low dissolved oxygen, lake user dissatisfaction during the process, and failure to refill. The technique is recommended for situations where susceptible species are the major nuisance and where prolonged (1-2 months) dewatering of sediments under rigorous conditions of heat or cold is possible.
(KEY TERMS: eutrophic; lake management; lake drawdown; macrophyte control; water quality).

INTRODUCTION

The protection, management, and restoration of lakes is the subject of an intense international research effort (USEPA, 1979). Water withdrawal or lake drawdown to manage nuisance macrophytes is an established technique. The objective is to retard macrophyte growth by destroying seeds and vegetative reproductive structures through exposure to drying and/or freezing conditions, and by altering their substrate by dewatering and consolidation of sediments. There are several secondary objectives which include turbidity control by sediment consolidation, reduction of nutrient release from sediments, management of fish populations and waterfowl habitats, repair of shoreline structures (e.g., dams, docks, and swimming beaches), and simultaneous use of other restoration methods such as sediment covering. Among the first uses of this technique was the control of vegetation in Tennessee Valley Authority reservoirs to suppress malaria-carrying mosquitos (*Anopheles* spp.) (Hinman and Hess, 1949).

Part of the current research program in eutrophication by the U.S. Environmental Protection Agency is to summarize the state of our knowledge of the effectiveness and problems with the several lake management techniques (Peterson, 1979). As part of that effort, this report was prepared to describe some case histories, to list those macrophyte species which are susceptible, resistant, or do not change after a summer, winter, or whole year drawdown, to evaluate the technique, and to make recommendations for its use and for further research.

REVIEW OF SELECTED CASE HISTORIES

Murphy Flowage, Wisconsin

Beard (1973) describes the response of Murphy Flowage to two consecutive winter drawdowns to control the dominant *Potamogeton robbinsii* (Robbin's pondweed), and subdominants *Nuphar* sp. (water lily), *Ceratophyllum demersum* (coontail), *P. natans* (floating-leaf pondweed), and *Myriophyllum* sp. (water milfoil). In 1967 and 1968 the flowage was lowered 1.5 m from November to March and refilled in April. There was a 92 percent reduction in area covered by macrophytes after two drawdowns, 89 percent of which occurred after the first drawdown. All five species were controlled or essentially eliminated. In 1969, the dominants were *Potamogeton natans*, which was common but not dominant before drawdown, and *Megalondonta beckii* (bur marigold), *Najas flexilis* (naiad), and *Potamogeton diversifolius*, which were previously rare.

In 1967, 42 percent of the flowage (303 ha) was obstructed with macrophytes to the extent that fishing was not possible. The first drawdown restored fishing to 87 percent of this area. The increased density of resistant plants had much less effect on fishing that the previous dominants. Although this was a successful treatment, resistant species began to spread after the second drawdown, and there was a heavy algal bloom in August in the year after drawdown. Dissolved oxygen remained adequate for fish in the channel during winter due to the flow through of water.

Further evaluation was ended when a flood destroyed the flowage in 1970.

Mondeaux Flowage, Wisconsin

Potamogeton robbinsii was also the dominant higher aquatic plant in Mondeaux flowage, which was drawn down during the winters of 1971-72 and 1972-73 (Nichols, 1975b). Forty

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percent (66 ha) of the 166 ha was free of nuisance plant growth after one drawdown, compared to complete coverage before. The second drawdown gave little additional control except for a further reduction in the abundance of *Nuphar variegatum*. In 1974 the abundance of plants returned to pre-drawdown levels and *Ceratophyllum demersum* became the dominant. In this regard, the treatment was unsuccessful. Dissolved oxygen levels during water withdrawal became very low but there was no fish kill.

Nichols (1975b) suggests that a drawdown every 2-3 years would be more effective than an annual water withdrawal since resistant plants might not then become established.

Louisiana Reservoirs

Lantz, *et al.* (1964), describe the lowering of water levels in the Louisiana reservoirs Anacoco, Bussey, and Lafourche, for vegetation management. Forty percent of Anacoco was closed to fishing due to macrophytes, but one year after a summer drawdown, only 5 percent was closed. An area of 283 ha, or 30 percent of the total surface area of Bussey Reservoir was closed, but after a fall-winter drawdown less than 12 ha remained closed. On Lafourche, 60 percent of the reservoir was cleared of nuisance vegetation by a drawdown from winter 1961 through summer 1963.

Drawdown each year was continued on Anacoco, although shifted to the winter season, and several other reservoirs were also drawn down for vegetation control and fish management (Lantz, 1974). Some macrophyte species were very susceptible to drawdown, while others increased or were unaffected (Table 1). Lantz suggests that the water level should be fluctuated each year for 2-3 years, rather than for 1 year, and then 2 years of no fluctuation before lowering again. This schedule gives the best plant control and fish production in Louisiana reservoirs. Lantz concludes that eradication using this or any other macrophyte control technique is unwise and probably not possible. Instead, he believes that the reservoir should be managed to retain desirable or innocuous vegetation, possibly through a combination of techniques.

Summary of Case Histories

The response of 63 macrophyte species to drawdown are listed in Table 1, along with the season of the drawdown and the literature source of the data. The table, modeled after Nichols (1974), illustrates the paucity of quantitative data and the apparent absence of a clear response in many species. Only three species, *Brasenia schreberi* (water shield), *Hydrochloa caroliniensis*, and *Potamogeton robbinsii* always seem to be controlled. *Nuphar* spp. and *Myriophyllum* spp. have also been reported to be controlled. *Alternanthera philoxeroides* (alligator weed), *Lemna minor* (duckweed), *Leersia oxyzoides* (cutgrass), and *Najas flexilis* always increase after a drawdown.

The case histories outlined above illustrate these common features of many drawdowns for macrophyte control:

1. The technique is species specific (e.g., *Potamogeton robinsii*).

2. The invasion of resistant species (e.g., *Najas flexilis*) may be rapid.

3. There may be undesirable changes in the system, including algal blooms and low dissolved oxygen.

EVALUATION OF DRAWDOWN

Macrophyte Control

Drawdown will bring about at least short-term (1-2 years) control of some, and usually most, rooted species if there is nearly complete dewatering of the sediments and a sufficient (1 month or more) period of cold (freezing) or heat. Rigorous conditions of exposure of the thallus and reproductive structures are apparently needed. In many lakes, ground water seepage is an important water source and dewatering of the sediment is very difficult after drawdown. Some species, including *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Lemna minor*, *Najas flexilis*, and *Potamogeton pectinatus* are strongly resistant to exposure (Goldsby, 1978; van der Valk and Davis, 1978; Wile and Hitchins, 1978). *M. spicatum*, a serious pest, requires 3 weeks or longer of dewatering during the winter to achieve control. The increased density of *N. flexilis* after drawdown (Tables 1 and 2) is thought to be due not only to the improved nutrient conditions which may occur in partially dewatered sediment, but also to the fact that some lake soils have remained moist after water withdrawal (Kadlec, 1962). Under such moist conditions, *Utricularia gibba* (bladderwort) and *Myriophyllum scabratum* will survive 2 or more weeks of exposure (Hall, *et al.*, 1946).

Beard (1973) attributed the control of *Nuphar* sp. in the Murphy Flowage, Wisconsin, to the light snow cover and the resultant deep frost layer in the exposed sediments. When the flowage was refilled portions of the bottom lifted, ripping *Nuphar* roots out. This condition of deep frost is not always achieved in winter (Gorman, 1979) and perhaps may be a condition limited to the northern climates of Wisconsin, Minnesota, and other areas of that latitude.

In some species reproductive structures are very resistant, and exposure can be stimulating to growth (Nichols, 1975a). van der Valk and Davis (1978) describe the drawdown of an Iowa prairie marsh in which seeds and other propagules of species such as *Potamogeton pectinatus*, *Scirpus validus* (soft stem bulrush), *Sparganium eurycarpum* (bur reed), *Lemna minor*, *Sagittaria latifolia* (arrowhead), and *Najas flexilis* remained viable at least 1 year in the exposed marsh soil.

It is not clear whether drawdown and exposure of lake sediments to dry, hot conditions is more effective than exposure to dry, freezing conditions. There have been many more reported winter drawdowns than summer (Table 1). The advantages of a winter drawdown are that there will be no invasion by terrestrial plants nor development of aquatic emergents, and little interference with recreation. However complete dewatering is more difficult, particularly in areas of heavy snow or of frequent winter rain. Reservoirs drawn down in winter can usually be refilled in spring, whereas refill in autumn after a

TABLE 1. Responses of Macrophyte Species to Annual (A), Winter (S), or Summer (S) Drawdown (numbers refer to authors in Literature Cited Section).

	Decreased			Increased			No Change		
	A	W	S	A	W	S	A	W	S
Alternanthera philoxeroides				11	8	15			
Asclepias incarnata		18							
Bidens sp.					1				14
Brasenia schreberi		15,18	14,16						
Cambomba caroliniana	12				15			15	
Carex spp.						14			
Cephalanthus occidentalis					15				
Ceratophyllum demersum	12	1		24	19,7		15	18	14
Chara vulgaris		15							
Dulichium arundinaceum						14			
Eichhornia crassipes	11,12				15				15
Eleocharis acicularis		18,22				14			
Elodea sp.	12								
Elodea canadensis		7			19				
Glyceria borealis					18				
Hydrilla verticillata					4				
Hydrochloa caroliniensis	21	22,21							
Hydrotrida caroliniana									
Jussiaea diffusa		8							
Lemna minor				24		14			
Leersia oryzoides				24	18	14			
Myriophyllum sp.	15	1							
Myriophyllum brasiliense									
Myriophyllum heterophyllum					15			15,8	
Najas flexilis				24	1,18,7	15,14		15	
Najas quadalupensis	11								
Najas minor									
Nelumbo lutea		15,8							
Nelumbo pentepetala								8	
Nuphar spp.		1,18,19							
Nuphar advena		21							
Nuphar variegatum									14
Nymphaea odorata		15							
Nymphaea tuberosa		18							
Polygonum coccineum					18,8		14		
Polygonum natans					18				
Pontederia cordata		18					11		14
Potamogeton sp.		16	16	9					
P. amphifolius		1,18			19				
P. crispus								7	
P. diversifolius		15			1			15	
P. epihydrous					18				
P. foliosus			14		18			7	
P. gramineus					18,19			7	
P. natans								1	14
P. pectinatus						24		7	
P. richardsonii					18			1	
P. robbinsii	11	19							
P. zosteriformis					19				
Potentilla palustris		18							
Sagittaria sp.				24	19	14	11		
Sagitarria heterophylla		18							
Salix interior					18				
Scirpus cyperinus	11					14			
Scirpus validus				24	19				14
Sium suave					18				
Sparganium chlorocarpum								1	14
Typha latifolia					18		11		14
Utricularia sp.								8	
Utricularis vulgaris		18,21							
Vallisneria americana	11							18	
Zizania aquatica									14
Zizaniopus miliacea		22							

summer drawdown may be difficult and may actually continue into winter. But winter drawdown may be adverse to projects where establishment of emergent vegetation for waterfowl habitat development was an object since these emergent species may be susceptible to the cold. Summer drawdown may not be possible on some reservoirs where an assured potable or industrial supply during summer drought is important, or where summer recreational uses could be seriously curtailed.

TABLE 2. Responses of Some Common Nuisance Aquatic Macrophytes to Drawdown (number of observations and seasons in parentheses; numbers refer to authors).

A. INCREASED

1. *Alternanthera philoxeroides* (alligatorweed) (3; all seasons) Ref: 8, 11, 15.
2. *Najas flexilis* (naiad) (7; all seasons) Ref: 1, 7, 14, 15, 24.
3. *Potamogeton* spp. (pondweed) (most increase or do not change; see Table 1).

B. DECREASED

1. *Chara vulgaris* (muskgrass) (1; winter) Ref: 15.
2. *Eichhornia crassipes* (water hyacinth) (2; annual) Ref: 11, 12.
3. *Nuphar* spp. (water lily) (3; winter) Ref: 1, 18, 19, 21.

C. NO CHANGE OR CLEAR RESPONSE

1. *Cabomba caroliniana* (fanwort) (3; annual, winter) Ref: 12, 15.
2. *Elodea canadensis* (elodea) (2; winter) Ref: 7, 19.
3. *Myriophyllum* spp. (milfoil) (5; annual, winter) Ref: 1, 8, 15.
4. *Utricularia vulgaris* (bladderwort) (3; winter) Ref: 8, 18, 21.

The decision to employ a summer or a winter drawdown for macrophyte control therefore must be based not only upon the rigorousness of the climate in a particular area, but also upon uses of the reservoir and any secondary management objectives. Until there has been further documentation, particularly of summer drawdown, it is not possible to recommend one or the other for control of a particular plant nuisance.

Positive and Negative Impacts of Drawdown

Game fishing often improves after a drawdown (Pierce, *et al.*, 1963; Beard, 1973). According to Lantz, *et al.* (1964), winter drawdowns in Louisiana are effective in removing populations of sunfish and shad, whereas summer drawdowns are more effective in preventing spawning of these species. In reservoirs where there have been 5 or more consecutive years of fluctuation there was an increase in fish standing crop, a rapid increase in game fish size and reproduction during the first years of fluctuation, and a leveling of standing crop change after several fluctuations (Lantz, 1974). Others (e.g., Halsey, 1958) have used drawdown as a means not only of increasing predation by concentrating fish but also as an opportunity to engage in a fish removal program. Where anadromous fish are involved, drawdown must be timed to minimize adverse effects on migration either through or out of the lake.

In many lakes, the sediments are loose and flocculent with high nutrient release, and may be a significant source of turbidity through the action of motor boats and wind. The experiments of Fox, *et al.* (1977), demonstrated that sun-dried sediments lose a great deal of water and remain consolidated after reflooding, and Kadlec (1962) reported that organic marsh sediments exposed to a summer drawdown became firm enough to walk on, and also remained firm after reflooding. Presumably reservoirs with turbidity problems could be improved by sediment consolidation.

Halsey (1958) has pointed out that drawdown can be an opportunity for lakeshore residents to improve docks, and dams, clean and repair shorelines, and deepen areas such as swim beaches. Also drawdown provides an opportunity to install other lake management devices such as sediment coverings.

Some impoundments lose their attractiveness to waterfowl after several years due to a succession of the macrophyte community towards plants which do not provide as much food to waterfowl as before (Kadlec, 1962). Drawdown has been used to renew such systems (e.g., Uhler, 1944; Steenis, 1950). Emergent plants attractive to waterfowl will develop from the seed bank in the sediments (van der Valk and Davis, 1978).

Algal blooms after reflooding may be one of the most negative impacts of drawdown, although such blooms are far more preferable than macrophytes for some boating activities. The cause of these algal blooms is not clear. It has been believed that drawdown and exposure of sediments, and the subsequent aeration and oxidation, may bring about considerable nutrient release at reflooding (Cook and Powers, 1958; Halsey, 1958; Kadlec, 1962; Wegener and Williams, 1974; Harris and Marshall, 1963). The experiments of Fox, *et al.* (1977), for muck-type sediments from Lake Apopka, Florida, indicate that drying and consolidation followed by reflooding does not bring about a breakdown of organic matter and nutrient release. However, Plotkin (1979) observed substantially increased interstitial phosphorus concentrations in rewetted, highly organic sediments following 2, 3, or 4 months of drying. Overlying water also became enriched and caused algal blooms. Similar to Lake Apopka sediments, these sediments (Long Lake, Washington) were consolidated by 50 percent, but the organic content did not change under experimental conditions. Nevertheless, the increased interstatial P levels were thought to be related to mineralization of organically bound P.

Fish kills may occur after drawdown, particularly in summer when rates of metabolism and oxygen demand of the sediments are higher (Geagan, 1960). However, dissolved oxygen following a 2 m summer drawdown of Long Lake, Washington (max. depth 3.5 m) remained above 5 mg/l with no apparent acute effects to fish (E. B. Welch, personal comm.).

The fauna of the littoral zone may exhibit great changes in species composition and density following drawdown and reflooding (Kadlec, 1962; Hunt and Jones, 1972; Wegener, *et al.*,

1974). While there may be an increase in invertebrate density after reflooding, as reported by Wegener, *et al.* (1974), there may be a great decrease in species diversity (Hunt and Jones, 1972). Not only is repopulation slow, but a summer drawdown and subsequent hardening of soils could reduce colonization by insects (Kadlec, 1962). Such changes in benthic invertebrates could be very detrimental to waterfowl and fish.

Failure to refill the reservoir after drawdown may be due to an insufficient watershed drainage area, to failure to close the dam at the proper time, and/or to unexpected drought. This problem points out the need to have an estimate of the water budget of the system before drawdown so that refilling time can be predicted.

Drawdown may also bring about other significant negative impacts, including those to downstream users of discharged water, to docks, and to potable water wells around the periphery of the lake.

Areas for Additional Research

The reports of success with drawdown to control macrophyte problems, with the exception of the Louisiana reservoirs (Lantz, 1974), have been short-term studies (1-2 years). As with many other lake manipulations, little followup has been possible. What interval between drawdowns is required to maintain vegetation control? Does the interval vary with summer or winter drawdowns?

Can the effectiveness of this technique be enhanced by combining it with other plant management methods such as sediment covering (Gorman, 1979; Cooke and Gorman, in press) or dredging (Fox, *et al.*, 1977)? The exposure of sediments provides an opportunity to proceed with other restorative steps, perhaps at a lower cost than when the lake is full.

What is the impact of dewatering on sediment chemistry and the release of material to the water column after reflooding? Do the factors vary with sediment type? Fox, *et al.* (1977), report that peat-type lake soils lose almost no water upon drying (7 percent in 180 days) but organic muck-type sediment consolidate 40-50 percent in the same period. Plotkin (1979) observed similar consolidation of highly organic sediment.

There is a need to develop a more systems-level perspective to the evaluation of this and all other lake restoration techniques. With regard to drawdown, major changes in nutrient cycling and energy-flow must occur as vertical zonation, water and nutrient income and flow through, consolidation of sediments, oxidation of detritus, elimination of plants, animals, and microbes which process organic matter, and changes in fish populations, take place. While questions about some or all of these processes have been addressed for some lake restoration techniques, little evidence is yet at hand for lake drawdown. An example of this approach is provided by the work of E. B. Welch, *et al.* (1979; personal communication). A 2 m drawdown was completed on Long Lake, Washington, during summer 1979. The dominant plant species is *Elodea densa* (water weed) and 40 percent of the P loading is internal, much of which could originate from *Elodea* and *Potamogeton* decomposition. Plants readily dried up upon dewatering and if regrowth is delayed 1-2 years a marked decrease in summer internal P loading may occur and result in less algae and clearer water.

SUMMARY AND RECOMMENDATIONS

Summary

Water level drawdown is an effective technique for at least the short-term control (1-2 years) of susceptible nuisance macrophyte species, and can be accomplished at relatively low cost without the introduction of chemicals or machinery. This technique is species specific and requires careful identification of the target plants before drawdown. Rapid establishment of resistant forms may occur. There is insufficient information to determine whether a summer or a winter drawdown will be most effective, but freezing to kill reproductive structures apparently required a deep frost which may not occur with heavy snow cover or with the milder, rainy winter which is found in large portions of the most macrophyte-impacted areas of the United States. It is apparently essential to achieve dewatering of the sediments, and this can be difficult where seepage is a significant portion of the water budget. This points out the need to determine a water budget before drawdown.

Among the positive changes which may occur, in addition to macrophyte control, are enhanced populations of game fish, consolidation of loose, flocculent sediments and thus possible control of turbidity generated by waves and motor boats, and the provision of an opportunity to improve docks, dams, and swimming areas.

There can be important negative changes following drawdown, including establishment of resistant macrophytes, algal blooms, fish kills, changes in littoral fauna, failure to refill, decline in attractiveness to waterfowl, lowered levels in potable water wells, and unavailability of open water or access to open water for recreation.

Recommendations

Lake level drawdown for macrophyte control is recommended for situations where prolonged (1 month or more) dewatering of lake sediments is possible under rigorous conditions of cold or heat, and where susceptible species (Table 2) are the major nuisances. As pointed out by Fox, *et al.* (1977), lakes with gradual basin slopes are ideal since small drops in lake level will expose large areas. The technique appears to have potential to be very effective if used in combination with other lake restoration methods such as dredging, sediment covering, game fish management, and herbicides. The introduction of exotic species, such as was done by Mather (1965) with the stocking of Israeli carp, may be very effective in combination with drawdown, but additional research is needed on possible adverse environmental effects before exotic species can be stocked in lakes and ponds.

An estimate of the water budget is very important so that the contribution of seepage, and thus the degree of dewatering, is known, and also the rate of refilling will be established.

There are many areas of additional research needed with the drawdown method, including long-term monitoring to establish frequency of drawdown needed, and studies of the contribution of reflooded consolidated sediments to the nutrient budget of the system, as well as the possible reduction of P loading internally because of macrophyte decrease.

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